The Institute of Research

LEHIGH UNIVERSITY

GPO PRICE $ ________

CFSTI PRICE(S) $ ________

Hard copy (HC) 1.00

Microfiche (MF) .50

ff 653 July 65

TO: Office of Grants and Research Contracts
Attention: Code SC
National Aeronautics and Space Administration
Washington, D. C. 20546

SUBJECT: First Semi-annual Progress Report
on
"Investigation of the Solidification, Structure and Properties of Eutectic Alloys Including Consideration of Properties Control"
NASA Research Grant: NGR-39-007-007

FACILITY FORM 602

N66-15814 (ACCESSION NUMBER)	(THRU)
12 (PAGES)	1 (CODE)
CR 69570 (NASA CR OR TMX OR AD NUMBER)	17 (CATEGORY)

SUBMITTED BY:

R. W. Kraft, Professor
Principal Investigator

R. W. Hertzberg, Assistant Professor
Co-investigator

DATE: December 22, 1965

First Semi-annual Progress Report
on
"Investigation of the Solidification, Structure and Properties of Eutectic Alloys Including Consideration of Properties Control"
NGR-39-007-007

The proposal for this grant indicated that if funds become available in the spring of 1965 it would be possible to plan ahead so that work could be initiated during the summer of 1965. Formal notification of the award of this grant was received in February 1965 but no expenditures were made until June 1965. Accordingly this progress report is being submitted six months from the effective initiation date (June 15, 1965) in accordance with a letter from John R. Craig III, Chief of Research Division, dated August 2, 1965, a copy of which is attached to the first copy of this report.

The work proposed under this grant consists of the initiation of a new program, different in many respects from previous work done at Lehigh University, rather than a continuation of a previous grant: it necessitated that new graduate assistants be attracted to the University to participate in the program. Portions of the experimental work have been delayed to some extent because all facilities of the Department of Metallurgical Engineering were moved early in the fall semester to a new (and more spacious) building as part of the University's expansion program. Much of the departmental equipment was inoperative for periods up to a few weeks and extraordinary demands were placed upon the time of all personnel engaged in this research during the move. For these reasons and because the graduate assistants did not begin their work until the beginning of the fall semester, the progress reported herein consists primarily of a brief discussion of preparatory work (literature review, plan of research, acquisition and modification of equipment and facilities, development of techniques and procedures) and the presentation of preliminary results. They are discussed in the next section together with plans for the immediate future. The final section on personnel is included in this first report since this is considered to be a key item of progress for the initiation of this new research program with the National Aeronautics and Space Administration.

RESEARCH IN PROGRESS

The research on this program is concerned with investigations of the mechanical properties of controlled eutectic alloys, viz. two phase binary alloys with extremely anisotropic microstructures produced by the unidirectional solidification of high purity melts under appropriate conditions. The general principles involved in making these materials, a summary of work done to date and the potentials for future applications are discussed in more detail in a soon-to-be-published review article by the principal investigator (1). Evidence that these materials show promise as a new approach to making whisker-reinforced composites is included in references (2) and (3) by the co-investigator of this grant.

The new work on this grant consists of investigations into the elevated temperature properties of selected controlled metallic eutectic alloys and another series of experiments designed to learn more about the fundamental aspects of fatigue of controlled eutectics with both lamellar and fibrous microstructures.

Microstructural Stability at Elevated Temperatures

The first phase of this work, high temperature properties, actually consists of two programs, both of which have been initiated. The first of these is a study of the effect of temperature and stress on the microstructural stability of controlled eutectics. Basically it is a continuation of the work of Graham and Kraft (4). In the latter research it was found that specimens of controlled lamellar Al-$CuAl_2$ eutectic retained a very high degree of microstructural anisotropy even when heated for prolonged periods of time (1200 hrs.) within 8°C of the eutectic temperature. This was considered to be a most encouraging indication that controlled eutectics might be eventually utilized in applications at a significant fraction of their absolute melting point. A model was developed in Graham's thesis which satisfactorily accounted for all experimental observations. However since only the effects of temperature were considered it is not known whether the simultaneous application of stress will affect the stability of the microstructure or alter the fundamentals of the coarsening process of these two phase alloys. The work in progress therefore consists in preparing specimens of controlled eutectic alloys and subjecting them to elevated temperatures under constant uniaxial loads applied in various directions with respect to the anisotropic microstructure. Lamellar Al-$CuAl_2$ and/or fibrous Al-Al_3Ni eutectics will be investigated and it is planned to load the specimens in both tension and compression if possible. Hopefully these experiments will elucidate the mechanism of coarsening of anisotropic two phase alloys under the influence of a variety of stress conditions and shed some light on whether stress-enhanced diffusion plays a significant role in these materials. The objective of this work is not to determine the creep-rupture behavior of these alloys but rather to establish the mechanisms of coarsening under the combined influence of stress and temperature. Actual progress to date has consisted of making some master heats and unidirectionally solidifying several ingots to provide stock for the heat treating experiments. It is anticipated that much of the raw data required for subsequent analysis will become available in the next reporting period.

Creep-rupture Properties

The second program concerned with the elevated temperature properties of controlled eutectics being done under this grant has a more practical orientation. It's objective is to determine the feasibility of developing creep-rupture resistant alloys with useful properties based upon the concept of in-situ fiber reinforcing via unidirectional solidification of binary eutectics. A comprehensive review of the literature including phase equilibria, fiber composites, and high temperature alloys plus information obtained from one other laboratory known to be engaged in a related program indicated that it would be logical (and wouldn't duplicate other efforts) to initiate this program with Co-Nb and Ni-Nb alloys. Both of these systems exhibit eutectic reactions, between Co-Co_2Nb and Ni-Ni_3Nb respectively. In each, calculations based upon crystal structure data and published phase diagrams indicate that the intermetallic phase will form the minor constituent (33% Co_2Nb and 21% Ni_3Nb respectively) and thus will probably form as either fibers or thin lamellae in a metallic matrix (1). Furthermore both alloys can be melted in facilities available within the department. Actual experimental work to date has consisted of adapting the melting equipment and techniques to this program and in preparing the first small heats (~100 gms) of both alloys. Microstructural examination has revealed that both alloys are lamellar in the as-cast condition. All indications based on prior experience (1,2,3) point to the fact that it will be possible to produce the desired anisotropic microstructure by unidirectional solidification. Preliminary results in the Ni-Ni_3Nb alloy hint that the published equilibrium diagram is in error as to the eutectic composition. This effect, if subsequently validated by future work, is small and will not affect the subsequent course of this work. Work during the next reporting period will consist of making larger ingots of these alloys, unidirectionally solidifying them, preparing creep-rupture test specimens, and preliminary testing. An important part of the evaluation program will consist of metallographic and electron fractographic studies of the specimens as an aid in determining the deformation, flow and fracture mechanisms of these eutectic composites at elevated temperatures.

Fatigue Studies

The third area of investigation is concerned with a study of the fatigue characteristics of controlled eutectic alloys. During the initial reporting period, considerable attention was given to the design of a test program which would hopefully yield the maximum amount of information. As a result, several decisions have been made concerning specimen design, type of test to be conducted and data to be obtained. It was decided that the simplest specimen geometry be utilized for the major portion of the study. This was based in large part upon the fact that most standard tensile specimens of the $Al-Al_3Ni$ (the principal system chosen for this investigation) have fractured in the shoulder section of the test bar (5). Consequently, a small rectangularly shaped coupon (approximately 1 1/2 x 1/2 x 1/16 inches) will be employed. It is intended that the fatigue behavior of the alloy will be evaluated by means of constant strain range tests such that fatigue life will be related to the cyclic plastic strain. To accomplish this goal the specimens will be bonded to a large cantilever beam made from a high yield strength to elastic modulus ratio material (e.g. 4340 steel). Completely reversed elastic bending in the carrier beam will transfer a constant cyclic strain to the eutectic coupons bonded on the beam. To insure constant strain in the coupons, the beam will be tapered in two sections along its length. In this way each tapered region will be subjected to a different but constant flexural stress. Consequently, two sets of specimens can be fatigued simultaneously but at different strain amplitudes. Another advantage of this specimen design and loading philosophy is that the small coupon size allows for preparation of a greater number of test samples for each ingot. As this report went to press specimens of unidirectionally solidified alloy were being prepared and equipment being readied for these experiments.

PERSONNEL

Appropriate biographical information on the principal investigator (R. W. Kraft) and co-investigator (R. W. Hertzberg) were included with the proposal and need not be repeated here. It is perhaps pertinent to note that a large portion of these individuals' time on this grant has been devoted to planning and guidance of the research assistants who are initiating their graduate thesis research on this grant.

As of the date of this report two graduate assistants are participating in this research; they are Lt. Cdr. Thomas Quinn, U.S.N., and Mr. W. Gary Watson.

Cdr. Quinn, who has a masters degree from the Naval Graduate School, is on detached duty from the Navy in order to obtain a Ph.D. degree. Since the Navy would not allow him to accept a stipend from another governmental agency (either directly or indirectly) while on active duty he is not drawing any pay from this grant. The research expenses (such as materials, supplies, etc.) connected with his work--the creep-rupture program on Co-Nb and Ni-Nb alloys--are being borne by the grant however and the work is considered part of this grant for reporting purposes. Mr. Watson, recently graduated from the State University of New York at Stony Brook, N. Y., with a B.S. degree in Engineering is working (initially) towards an M.S. degree. He will use the first phases of the microstructural deterioration studies as his thesis research.

Beginning early in 1966 another research assistant in the person of Mr. Solomon Musikant will begin working on this grant. Mr. Musikant, who has an M.S. degree, plans to take a leave of absence from his employer (he is presently an assistant to the vice-president) to obtain a Ph.D. degree. Initially he will assist Dr. Hertzberg in the fatigue studies of controlled eutectics.

The principal investigator and co-investigator feel particularly pleased in having attracted to this program three capable graduate assistants, two of them--Cdr. Quinn and Mr. Musikant--men of considerable maturity and experience. It is therefore anticipated that considerable tangible progress will be made in the next reporting period now that most of the preliminary work is finished.

REFERENCES

1. R. W. Kraft, "Controlled Eutectics" (a review), accepted for publication in J. of Metals. To be published early in 1966.

2. R. W. Hertzberg, "Potential of Unidirectionally Solidified Eutectic Alloys as Reinforced Composites," chapter in Fiber Composite Materials, Am. Soc. for Metals, Metals Park, Ohio, 1965.

3. R. W. Hertzberg, "In-situ Fiber Growth" chapter contributed to forthcoming Addison Wesley text on fiber composites. To be published in 1966.

4. L. D. Graham and R. W. Kraft, "Coarsening of Eutectic Microstructures at Elevated Temperatures," accepted for publication in Trans. Met. Soc. AIME. To be published probably in Vol. 236, No.1, Jan. 1966.

5. R. W. Hertzberg, F. D. Lemkey and J. A. Ford, "Mechanical Behavior of Lamellar (Al-$CuAl_2$) and Whisker-type (Al-Al_3Ni) Unidirectionally-Solidified Eutectic Alloys," Trans. Met. Soc. AIME, V.233, Feb. 1965, pp.342-354.